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U1S S1990 S2017

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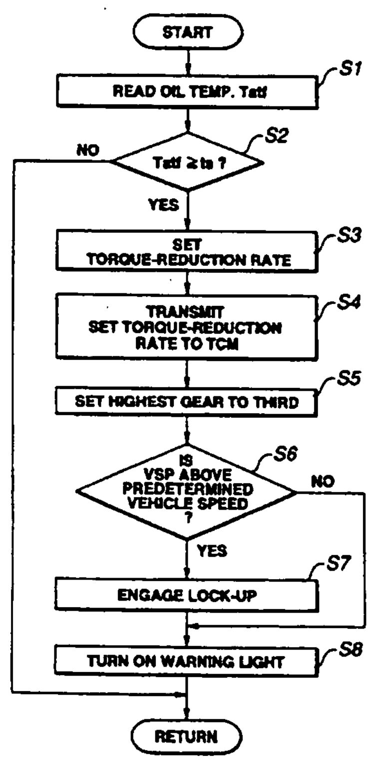
INT CL^6 B60K 41/04 41/06 41/08 41/10, F02D 29/00 29/02
Online: WPI

(54) Regulating transmission fluid temperature by controlling the vehicle engine

(57) The temperature of transmission fluid in a vehicle automatic transmission is sensed directly or indirectly S1 and when this temperature is above a predetermined value S2, or alternatively, a predicted future value is above a predetermined value, torque reduction means connected to the vehicle engine control system causes the engine output torque to be reduced S3, S4. Torque reduction may be by throttle, air/fuel ratio, or ignition timing control and on the basis of a map in the control system memory S3. Additionally, the top gear of the transmission may be inhibited S5 and, if the vehicle speed is above a predetermined value S6, torque converter lock-up may be engaged S7. A warning light for the driver may be lit S8.

FIG.4



GB 2 320 339 A

FIG.1

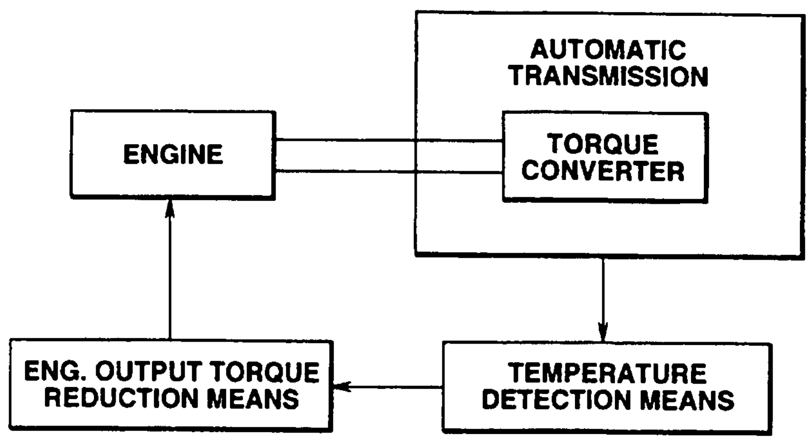

AUTOMATIC
TRANSMISSION
ENGINE
TORQUE
CONVERTER
ENG. OUTPUT TORQUE
REDUCTION MEANS
TEMPERATURE
DETECTION MEANS

FIG.2

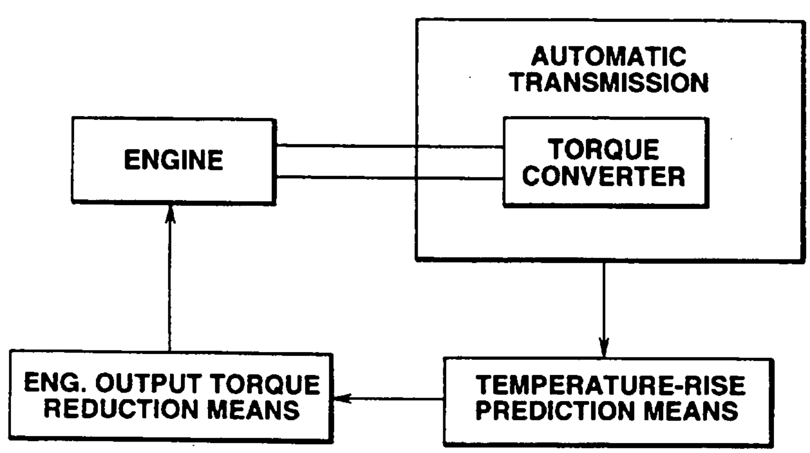

AUTOMATIC
TRANSMISSION
ENGINE
TORQUE
CONVERTER
ENG. OUTPUT TORQUE
REDUCTION MEANS
TEMPERATURE-RISE
PREDICTION MEANS

FIG.3

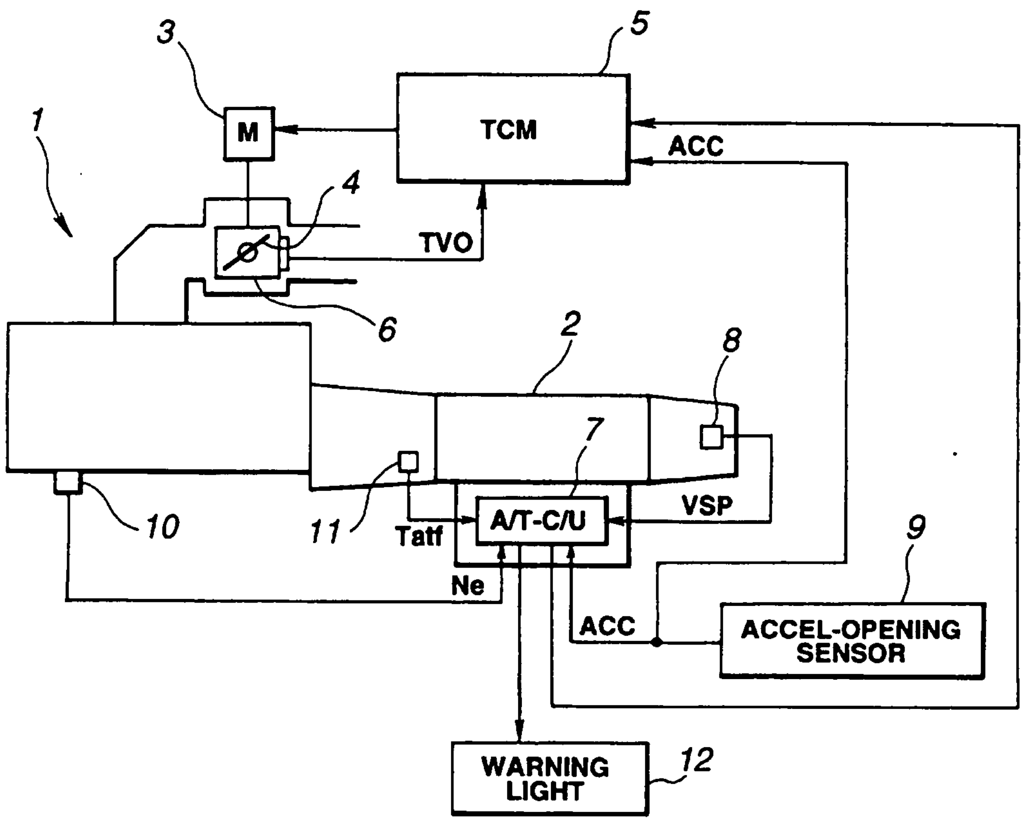

3
5
1
M
TCM
ACC
4
TVO
6
2
8
7
10
11
Tatf
A/T-C/U
VSP
9
Ne
ACC
ACCEL-OPENING SENSOR
WARNING LIGHT
12

FIG.4

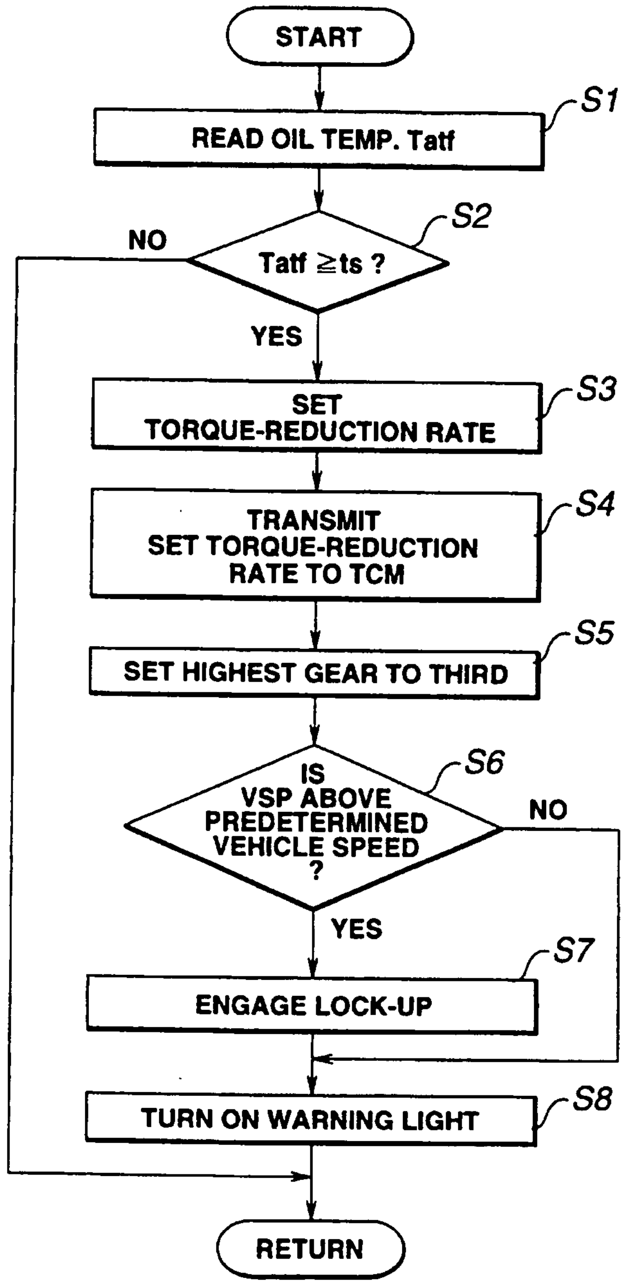
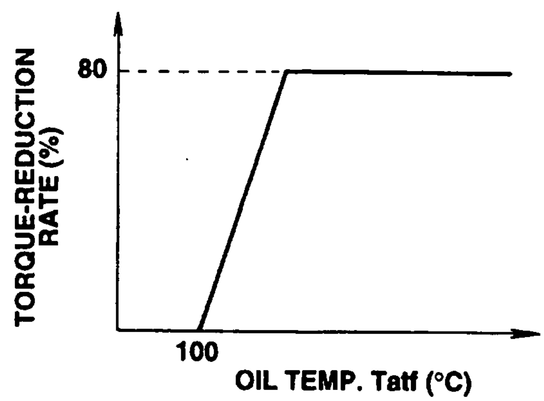
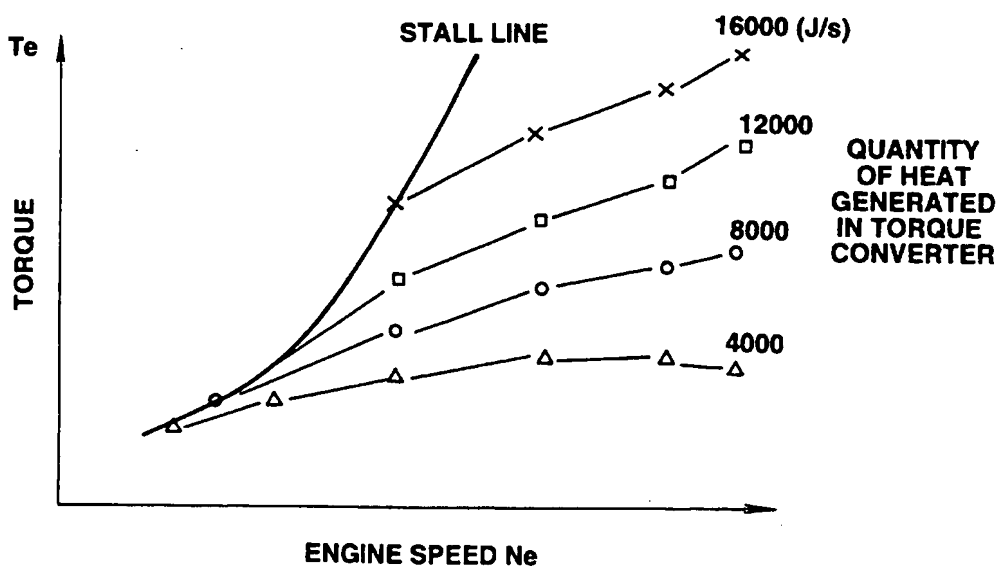

START
READ OIL TEMP. Tatf
S1
Tatf ≥ts ?
S2
NO
YES
SET TORQUE-REDUCTION RATE
S3
TRANSMIT SET TORQUE-REDUCTION RATE TO TCM
S4
SET HIGHEST GEAR TO THIRD
S5
IS VSP ABOVE PREDETERMINED VEHICLE SPEED ?
S6
NO
YES
ENGAGE LOCK-UP
S7
TURN ON WARNING LIGHT
S8
RETURN

FIG.5



TORQUE-REDUCTION RATE (%)
80
100
OIL TEMP. Tatf (°C)

FIG.6



Te
TORQUE
STALL LINE
16000 (J/s)
12000
8000
4000
QUANTITY OF HEAT GENERATED IN TORQUE CONVERTER
ENGINE SPEED Ne

FIG.7A

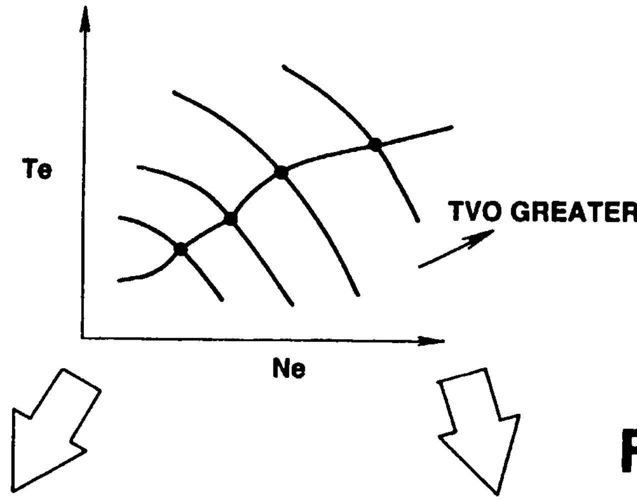


FIG.7B

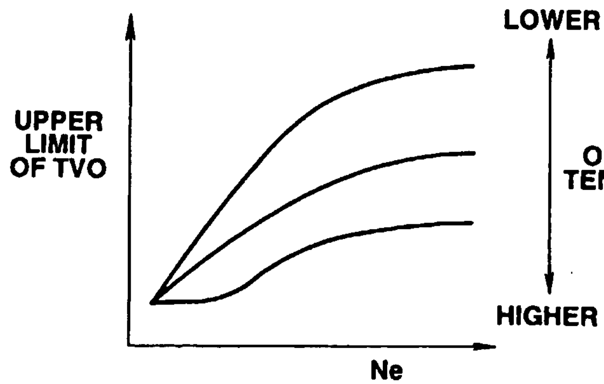


FIG.7C

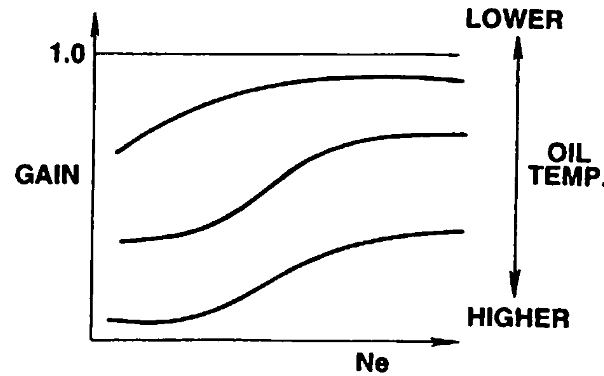


FIG.8

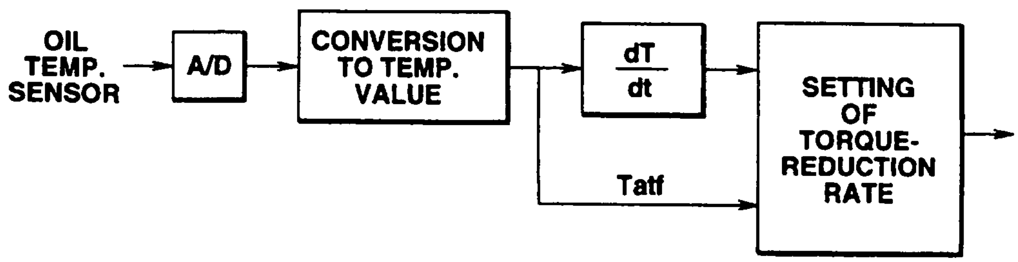

OIL
TEMP.
SENSOR
A/D
CONVERSION
TO TEMP.
VALUE
dT
dt
Tatf
SETTING
OF
TORQUE-
REDUCTION
RATE

FIG.9

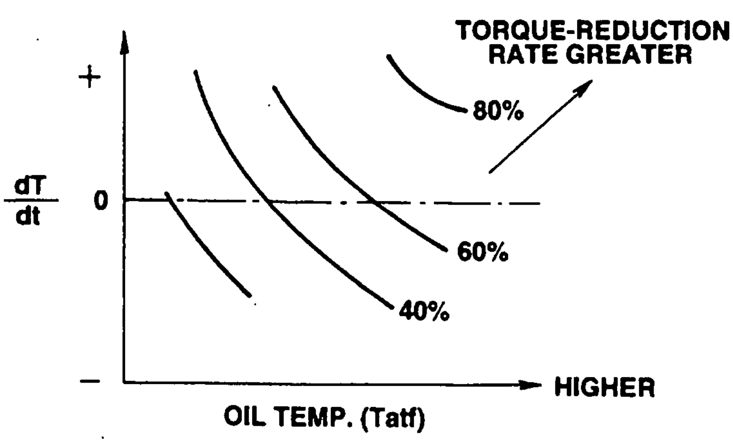
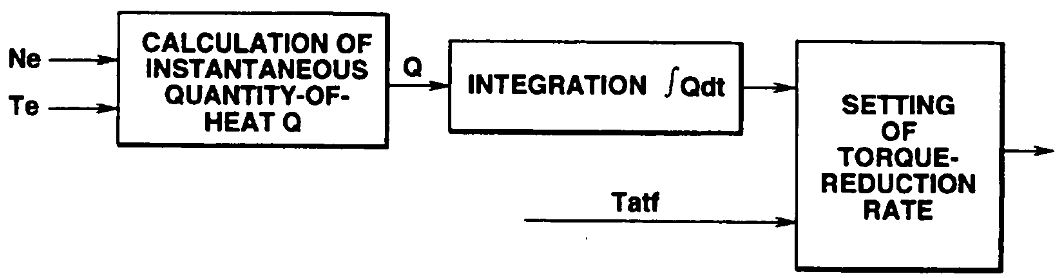

TORQUE-REDUCTION
RATE GREATER
+
dT
dt
0
−
80%
60%
40%
HIGHER
OIL TEMP. (Tatf)

FIG.10


Ne
Te
CALCULATION OF INSTANTANEOUS QUANTITY-OF-HEAT Q
Q
INTEGRATION ∫Qdt
Tatf
SETTING OF TORQUE-REDUCTION RATE

2320339

CONTROL SYSTEM FOR CONTROLLING TEMPERATURE OF TRANSMISSION FLUID IN AN AUTOMATIC POWER TRANSMISSION WITH A TORQUE CONVERTER IN AUTOMOTIVE VEHICLES WITH AN ELECTRONIC ENGINE CONTROL SYSTEM

The contents of Application No. TOKUGANHEI 8-333496, filed December 13, 1996, in Japan is hereby incorporated by reference.

The present invention relates to an automatic power transmission control system combined with an electronic engine control system, and specifically to techniques for preventing excessive temperature-rise in transmission fluid (often called transmission oil) within an automatic power transmission with a torque converter in automotive vehicle employing an electronic engine control system.

Recently in automatic transmissions using a torque converter via which the engine-power output is transmitted to the transmission input shaft, there have been developed and proposed various methods for preventing degradation of transmission fluid, or degradation of each individual friction element, or degradation of each sealing member such as a sealing ring usually made of special rubber-like material which may occur owing to a temperature rise in transmission fluid. As an example of a method for preventing such degradation of the transmission fluid, frictional elements, sealing members or the like owing to a temperature rise in transmission fluid, in an automatic

transmission with a so-called lock-up torque converter, it is well known to properly timely enlarge a lock-up zone (a full lock-up zone), at which the lock-up clutch is engaged, when the temperature of transmission fluid excessively rises and then exceeds or may exceed a permissible temperature value. As is generally known, there is a slip (i.e., internal slippage of the torque converter) of the torque-converter driven member (e.g., a turbine runner) relative to the torque-converter driving member (e.g., a pump impeller). The enlarged lock-up zone contributes to reduction of a quantity of heat generated in transmission fluid due to the previously-noted slip (heat coming from the workings of the torque converter), part of heat coming from the engine, and frictional heat developed by frictional effects (including fluid-flow resistance) of layers of transmission fluid passing over each other. Such a method for prevention of temperature-rise in transmission fluid has been disclosed in Japanese Patent Provisional Publication Nos. 62-205829, 62-209265, and 5-302671. However, during up-hill driving, the vehicle speed may be generally lowered, and the automatic transmission range gear shifting (for example downshift) may occur frequently or the accelerator-pedal may be often released. Even with the lock-up zone enlarged, the lock-up clutch tends to shift to the other zone (namely an open-converter zone at which the lock-up clutch is released) without staying in the full lock-up zone for a long time. Under such vehicle/engine operating conditions (with frequent shifting actions, changes in the vehicle speed, and/or changes in the throttle opening), it is difficult to effectively rapidly prevent the temperature rise in transmission fluid. In recent

years, an electronic control unit (C/U or ECU) or an electronic control module (ECM) which executes an automatic shifting action and a lock-up clutch control (simply a lock-up control), is integrally provided in an transmission case. In this case, in order to protect electronic computer components contained in the ECU and to avoid the damage to the computer components, it is necessary to effectively suppress excessive temperature rise in transmission fluid. It is difficult to effectively rapidly suppress the temperature-rise in transmission fluid by way of only enlarged lock-up zone.

Accordingly, it **would be desirable to be able to** provide a control system for controlling or regulating a temperature of transmission fluid in an automatic power transmission in automotive vehicles with an electronic engine concentrated control system, which avoids the aforementioned disadvantages of the prior art.

It **would also be desirable to be able to provide** an electronic control system for effectively rapidly controlling or regulating a temperature of transmission fluid in the automatic transmission within a permissible temperature value and for suppressing excessive temperature rise in the transmission fluid, in an automatic power transmission where an electronic control system unit is integrally provided in the transmission case.

The present invention provides a control system for regulating temperature of transmission fluid in an automatic power transmission with a torque converter in an automatic vehicle with an electronic engine control system, **comprising** temperature detection means for

detecting a transmission temperature correlating with a temperature of transmission fluid, and engine output torque reduction means for continuously reducing engine output torque, when the transmission temperature detected by the temperature detection means is above a predetermined temperature value. The control system for regulating a temperature of transmission fluid, may further comprise a temperature rise prediction means for predicting a rise in the transmission temperature above a predetermined temperature value. The engine output torque reduction means may reduce the engine output torque when the temperature rise prediction means determines that a temperature rise predictive of the transmission temperature above the predetermined temperature value occurs. Preferably, the transmission temperature correlating with a temperature of transmission fluid is a transmission-fluid temperature itself. Alternatively, the transmission temperature correlating with a temperature of transmission fluid may be a temperature of atmospheric air around the transmission fluid or a temperature of a transmission case. More preferably, the engine output torque reduction means may reduce the engine output torque down to a lower output torque as the transmission temperature becomes higher, or as a time rate of rise in the transmission temperature becomes higher. The control system for regulating a temperature of transmission fluid, may further comprise a lock-up zone enlargement means for enlarging a lock-up zone of a lock-up clutch in an automatic transmission with a lock-up torque converter, while the engine output torque reduction means continuously reduces the engine output torque. The control system for regulating a temperature of

transmission fluid, may further comprise a highest gear limitation means for limiting a shift gear range of the automatic transmission down to a lower speed gear, while the engine output torque is continuously reduced by the engine output torque reduction means. The control system for regulating a temperature of transmission fluid, may further comprise a warning means for signaling for a particular state in which the engine output torque is continuously reduced by the engine output torque reduction means.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram explaining a fundamental concept of one embodiment of a control system for regulating a temperature of transmission fluid in an automatic power transmission, according to the invention.

Fig. 2 is a block diagram explaining a modification of a control system for regulating a temperature of transmission fluid in an automatic power transmission, according to the invention.

Fig. 3 is a system block diagram illustrating the control system for regulating the transmission-fluid temperature, as related to Figs. 1 and 2.

Fig. 4 is a flow chart illustrating detailed steps of a transmission-fluid temperature control routine, performed by the control system of the embodiment.

Fig. 5 is a graph (a map data) illustrating the relationship between a transmission-fluid temperature (T_{atf}) and a reduction rate in engine output torque.

Fig. 6 is a graph showing characteristic curves representative of the correlation among the engine output torque (Te), the engine speed (Ne), and several

quantities of heat generated in transmission fluid (for example 4000, 8000, 12000, and 16000 joules/sec).

Fig. 7A is a graph illustrating characteristic curves representative of the relationship among the engine output torque (Te), the engine speed (Ne), and several throttle openings (TVO), based on a characteristic curve of a permissible quantity-of-heat derived from the graph shown in Fig. 6.

Fig. 7B shows characteristic curves for the upper limit of throttle opening (TVO), the engine speed (Ne), and the oil temperature (T_{atf}).

Fig. 7C shows characteristic curves for the control gain, the engine speed (Ne), and the oil temperature (T_{atf}).

Fig. 8 is a block diagram illustrating a modified transmission-fluid temperature control system (as related to Fig. 2) which utilizes the time rate-of-change (dT_{atf}/dt) of the detected oil temperature (T_{atf}).

Fig. 9 is a graph illustrating the relationship among the derivative (dT/dt) of the oil temperature, the instantaneous oil temperature value (T), and the torque-reduction rate expressed in a percentage (%).

Fig. 10 is a block diagram illustrating another modified transmission-fluid temperature control system (as related to Fig. 2) which utilizes the value of the integral $\int Qdt$ of the instantaneous quantity-of-heat Q.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, particularly to Fig. 3, the transmission-fluid temperature control system of the invention is exemplified in a typical planetary-gear type four-speed automotive automatic transmission with a so-called lock-up torque converter in an automotive vehicle with an electronic engine control

system (ECU or C/U), sometimes called an electronic concentrated engine control system. The engine-power output (or the output torque) generated by an internal combustion engine 1 is transmitted via the lock-up torque converter, employing therein a lock-up clutch, to the transmission output shaft of the planetary-gear type automatic transmission (or the multi-speed type automatic transmission) 2, and then transmitted through a differential (not shown) to drive wheels (not shown). Alternatively, the typical planetary-gear type automatic transmission may be replaced with a continuously-variable transmission (or a stepless automatic transmission). As seen in Fig. 3, a throttle valve 4 is disposed in the intake-air passageway of the internal combustion engine 1. The opening and closing of the throttle valve 4 is driven by means of an electric motor 3, thereby adjusting the amount of intake air flowing through the throttle 4. The motor 3 is driven in response to a control signal generated from a throttle control module 5 (simply abbreviated to "TCM"). The TCM 5 receives an accel-opening indicative signal ACC from an accel-opening sensor 9 which monitors the amount of depression of the accelerator pedal or throttle pedal operated by the driver. The TCM 5 also receives an actual throttle opening indicative signal TVO from a throttle sensor 6. For example, the system of the shown embodiment uses a typical throttle position sensor (a potentiometer) as the throttle sensor 6. As is generally known, the voltage signal from the throttle position sensor (TPS) is low during engine idling, and increases as the throttle angle is increased. The TCM 5 is responsive to the input information signal ACC from the sensor 9 for setting or determining a target throttle

opening TVO_{ta} and for properly driving the motor 3 so that the actual throttle opening TVO detected by the sensor 6 is adjusted to the target throttle opening TVO_{ta} by way of a feedback control. As seen in Fig. 3, the automatic transmission control unit 7 (A/T-C/U) is integrally provided in the transmission case of the automatic transmission 2, for performing an automatic shift control and a lock-up control including a lock-up shift timing control, or the like. The automatic transmission control unit 7 is arranged at the bottom of the transmission case, together with a control valve assembly including various valves such as electronically controlled solenoid shift valves, a pressure regulator valve, a lock-up control valve or the like, and power transistors driving the respective solenoid valves. The automatic transmission control unit 7 receives a vehicle-speed indicative signal VSP from a vehicle speed sensor 8 which operates on a pulse-counter principle, an accel-opening indicative signal ACC from the accel-opening sensor 9, an engine-speed indicative signal Ne from an engine-speed sensor 10 which operates on a pulse-counter principle, and an oil-temperature indicative signal T_{atf} from an oil-temperature sensor 11. The oil-temperature sensor 11 is located on the torque converter for monitoring a temperature of transmission fluid (transmission oil) of the automatic transmission 2. The A/T-C/U 7 executes the automatic shift control, the lock-up control and the like, on the basis of the input information signals VSP, ACC, Ne and T_{atf}. The A/T-C/U 7 also executes a transmission-fluid temperature control routine in accordance with the flow chart shown in Fig. 4, for the purpose of preventing the detected oil temperature T_{atf} from exceeding a predetermined

permissible temperature ts. As will be fully described later by reference to the flow chart (the transmission-fluid temperature control routine) of Fig. 4, the A/T-C/U 7 functions as an engine output torque reduction means, a lock-up zone enlargement means, and a downshift means. The transmission-fluid temperature control routine hereinbelow described in detail in accordance with the flow chart of Fig. 4. This routine is usually executed as time-triggered interrupt routines to be triggered every predetermined intervals.

First, in step S1, an oil temperature value T_{atf} detected by the oil-temperature sensor 11 is read. In step S2, a test is made to determine whether the oil temperature T_{atf} is above a predetermined temperature ts (a permissible temperature of transmission fluid). When the answer to step S2 is in the negative (NO), that is, in case of $T_{atf} < ts$, the current routine (the current execution cycle) terminates. Conversely, when the answer to step S2 is in the positive (YES), that is, in case of $T_{atf} \geqq ts$, step S3 occurs. In step S3, a torque-reduction rate is set or determined on the basis of the detected oil temperature T_{atf}, in order to lower the temperature of transmission fluid by forcibly reducing torque output from the engine 1. As seen in Fig. 5, the previously-noted torque-reduction rate expressed in a percentage (%) is pre-programmed in such a manner as to be set at a zero percentage when the detected oil temperature T_{atf} is less than a first predetermined temperature value (for example 100 °C), and to be gradually increased until a second predetermined temperature value (greater than the first predetermined temperature value) has been reached from the first predetermined temperature value (e.g., 100 °C), and to

be held at a constant value such as 80 % after the second predetermined temperature value has been reached. The map data shown in Fig. 5 is pre-stored in the computer memory (ROM) constructing part of the automatic transmission control unit 7. The torque-reduction rate versus oil-temperature (T_{atf}) characteristic is aimed at avoidance of excessive torque reduction within a comparatively low oil temperature range of the oil temperature T_{atf}, and at effective rapid drop in the oil temperature T_{atf} with great torque reduction within a comparatively high oil temperature range. As appreciated from the test results shown in Fig. 6, the quantity of heat generated in the torque converter correlates with both the engine speed (Ne) and the engine output torque (Te). In Fig. 6, the heavy solid line or curve indicates a stall line being obtained through an automatic-transmission stall test which is generally made to determine the maximum engine rotational speed (the top engine speed) when driving through the automatic transmission at full throttle usually in the D (drive) range with the vehicle stationary. The stall test or check is experimentally assumed by the inventor of the present application. As can be appreciated from the stall check of Fig. 6, the quantity of heat generated in the torque converter increases as the output torque from the engine 1 is increased. The inventor discovers that it is possible to effectively lower the temperature of transmission fluid by reducing the engine output torque Te and thus by reducing the quantity of heat generated in the torque converter. Subsequently to step S3, step S4 is entered. In step S4, the set torque-reduction rate determined at step S3 is sent to the TCM 5, for decreasingly compensating for the target throttle

opening TVO_{ta}, which is based on the accel-opening ACC, in response to the set torque-reduction rate. Thus, the throttle opening of the throttle valve 4 is controlled or regulated on the basis of the compensated target throttle opening TVO_{ta}. This forcibly reduces the amount of intake air introduced into the engine 1 when the detected oil temperature T_{atf} exceeds the previously-noted predetermined temperature value (e.g., 100 °C). Therefore, torque (Te) output from the engine 1 can be continually reduced, thereby ensuring a smooth drop in oil temperature T_{atf} down to the predetermined temperature. Then, step S5 is entered. In step S5, the selectable highest gear is limited to or set at the third-speed gear (3rd), although the highest gear will be set at the fourth-speed gear (4th) usually, that is, when the oil temperature is below the predetermined temperature value and within a proper transmission-fluid operating temperature range. That is to say, step S5 limits the automatic shift control from an usual shift gear range of four forward speeds (1st, 2nd, 3rd, 4th gears) and reverse (R) gear positions to a limited shift gear range of three forward speeds (1st, 2nd, 3rd gears) and reverse (R). This inhibits the transmission to be automatically upshifted to the 4th gear even in the engine/vehicle operating conditions where the transmission may be shifted into the 4th gear if the usual shift schedule is applied, and in lieu thereof the shifting of the transmission is limited to or downshifted into the 3rd gear (serving as the highest gear ratio within the limited shift gear range) even under such engine/vehicle operating conditions. Such downshifting to the 3rd gear generally causes a rise in engine revolutions and thereafter an engine control follows to

properly reduce the engine output torque. As a consequence, the quantity of heat generated in the torque converter can be effectively reduced. It will be easily understood that a combination of the torque-reduction control given at steps S3 and S4 and the highest gear limitation control (or one-step downshift control) given at step S5 is more effective to a rapid drop in the quantity of heat generated in the torque converter, rather than using only the torque-reduction control of steps S3 and S4. That is, the preferable combination of steps S3, S4 and S5 contributes to a rapid drop in the oil temperature T_{atf}, and effectively prevents degradation of transmission fluid, and additionally protects the computer components of the automatic transmission control unit 7 from heat damage. Thereafter, in step S6, a test is made to determine the vehicle speed VSP detected by the vehicle speed sensor 8 is above a predetermined vehicle speed. When the answer to step S6 is affirmative (YES), step S7 occurs. In step S7, the lock-up clutch employed in the torque converter is engaged (lock-up is turned ON). When the answer to step S6 is negative (NO), the procedure jumps to step S8. The lock-up is generally turned ON (engaged) during the straight-ahead driving at a vehicle speed above a predetermined vehicle speed at the highest gear ratio. As discussed above, the flow from step S5 via step S7 to step S8 permits the lock up to be turned on even when the vehicle is traveling at a speed greater than the predetermined speed with the transmission shifted in the 3rd gear. Practically, the flow from step S5 via step S6 to step S7 contributes to enlargement of the lock-up zone. In this manner, when the lock up is turned on, the torque-converter driving member (that is, a

turbine runner) is coupled via the lock-up clutch directly with the torque-converter driven member (that is, a pump impeller), thereby preventing or suppressing the internal slippage of the torque-converter driven member relative to the torque-converter driving member. This avoids generation or development of frictional heat resulting from frictional effects of layers of transmission fluid passing over each other. On the contrary, when the vehicle is running at a speed below the predetermined vehicle speed, the flow from step S3 via step S4 to step S5 contributes to suppression of the quantity of heat generated in the torque converter. In the shown embodiment, the torque-reduction control (see steps S3 and S4), the one-step downshift control (or the lock-up zone enlargement)(see step S5), and the lock-up control (see steps S6 and S7) are executed in accordance with a series of control flow from step S1 through steps S2, S3, S4, S5 and S6 to step S7. Alternatively, lock-up zone enlargement may be achieved only when the oil temperature T_{atf} is high. When the engine/vehicle conditions are out of the previously-noted enlarged lock-up zone, a torque-reduction control and/or a forcible downshift control (or a highest gear limitation control or inhibition of shifting to the highest gear ratio) may be made.

In step S8, a warning light 12, which is usually mounted on the instrument panel of the vehicle is turned on to warn the driver that the previously-noted torque-reduction control and the inhibition of shifting to the highest gear (4th gear) are now executed. Step S8 corresponds to a warning means. The warning means (the warning light 12) certainly signals the driver that the torque-reduction control is now executed and thus

prevents the driver from confusing the lowering of engine-power output based on engine failure and the lowering of engine-power output based on the previously-noted torque-reduction control for effective drop in transmission-fluid temperature.

In the embodiment set out above, although the torque-reduction rate is set or determined on the basis of the detected oil temperature T_{atf} from the pre-stored map data (see Fig. 5), the torque-reduction rate of step S3 may be determined or set on the basis of an upper limit of throttle opening TVO, whose upper limit are derived from several characteristic curves shown in Figs. 7A, 7B and 7C. In Fig. 7A, the undulated line extending from the lower left to the upper right is a characteristic curve indicative of a permissible quantity of heat derived from the graph of Fig. 6 showing the correlation among the engine output torque (Te), the engine speed (Ne) and the quantities of heat generated in the torque converter (precisely the transmission fluid). That is, the graph shown in Fig. 7A is representative of the relationship among the engine output torque (Te), the engine speed (Ne), and the throttle openings (TVO) for example 1/8. 2/8, 3/8 ···, based on the characteristic curve of the permissible quantity of heat generated in the torque converter. As can be appreciated from the characteristic curves shown in Fig. 7A, the upper limit of the throttle opening TVO necessary for limiting the quantity of heat generated in the torque converter in every engine revolution speeds within the permissible quantity-of-heat can be determined to be set at a greater value, as the engine speed Ne increases. In other words, when the engine speed Ne becomes lower, it is necessary to limit the throttle opening TVO to a smaller throttle

angle opening in order to excessive quantity of heat generated in the torque converter. Even in such a quantity of heat that, steadily, there is less possibility that the oil temperature T_{atf} exceeds a permissible temperature, if the oil temperature T_{atf} is high, adjustment of the quantity of heat generated in the torque converter to a smaller value may contribute to a rapid drop in the oil temperature T_{atf}. Thus, as seen in Fig. 7B, as the engine speed becomes higher and also the oil temperature T_{atf} becomes higher, preferably the upper limit of the throttle opening TVO may be set at a lower throttle angle opening, and the set throttle-opening upper limit may be output to the TCM 5 as the torque-reduction rate or amount. Then, the TCM 5 may control or regulate the actual throttle opening so that the target throttle opening TVO_{ta} never exceeds the set throttle-opening upper limit. In lieu of the previously-noted proper setting of the upper limit of the throttle opening TVO, as seen in Fig. 7C, a gain necessary for conversion of the accel opening ACC to the target throttle opening TVO_{ta} may be properly set in a manner so as to exhibit the same tendency as proper setting of the throttle-opening upper limit shown in Fig. 7B. That is to say, in Fig. 7C, as the engine speed Ne becomes lower and also the oil temperature T_{atf} becomes higher, it is preferable that the gain is set at a lower value, so that the actual throttle opening tends to be limited or suppressed to a smaller throttle angle opening even when the accel opening ACC is a greater opening. This effectively reduces the engine output torque. As set forth above, the system of the embodiment performs the torque-reduction control on the basis of comparison between the detected value of oil temperature

(transmission-fluid temperature) and the predetermined permissible temperature (for example the first predetermined temperature value such as 100 °C). Alternatively, as shown in Figs. 8 through 10, the system may execute a predictive engine output torque reduction control, a predictive downshift control (or predictive highest gear limitation control) and/or a predictive lock-up zone enlargement, while predicting a particular temperature-rise state where the oil temperature T_{atf} will exceed the predetermined permissible temperature value soon.

Referring now to Fig. 8, there is shown a first modification of the transmission-fluid temperature control system according to which the torque reduction control can be executed, predicting the time rate of rise in the oil temperature. The first modification comprises a transmission-oil temperature-rise prediction means, as fully described later. As appreciated from the block diagram shown in Fig. 8, the input information signal from the oil temperature sensor 11 is sent to the analog-to-digital converter (A/D converter). The A/D converter converts the input signals (usually analog voltage signals) from the oil temperature sensor 11 to digital signals since the computer (the microcomputer) included in the transmission-fluid temperature control system is designed to operate only on digital signals. Although it is not clearly shown, the previously-noted A/T-C-U 7 (the automatic-transmission control unit) is usually constructed by a microcomputer. Since the construction of the microcomputer for the vehicle electronic control system is conventional, detailed description of the microcomputer is omitted. Hereinbelow described in

brief is the construction of the microcomputer which is able to be used for the transmission-fluid temperature control system of the invention. The microcomputer has a processor (central processing unit abbreviated to "CPU") for various arithmetic calculations involving the calculations in the routine shown in Fig. 4, or arithmetic calculations shown in Figs. 8 or 10), an input/output interface including an analog-to-digital (A/D) converter for converting an analog input information or data, for example the vehicle sensor signals T_{atf}, Ne, ACC and VSP, to a digital signal, and also including a digital-to-analog (D/A) converter and a special driver to handle or drive a larger load, that is, the electric motor 3 provided for opening and closing the throttle valve 4, memories (ROM, RAM) for pre-storing programs shown in Fig. 4, and for permanently storing a predetermined, programmed information (see Figs. 5, or 7B and 7C, or Fig. 9) and for temporarily storing the results of ongoing arithmetic calculations (see steps S1, S2, S3, S5, S6 of Fig. 4, or see Figs. 8 and 10). The previously-noted input and output interface circuits can be constructed individually, or in lieu thereof integrally formed as an input/output interface unit. Returning again to Fig. 8, the digital signal from the A/D converter is converted to a temperature-value data. The temperature-value data is transmitted to a differentiator for differentiating the temperature value data to obtain a differentiated value, that is, a time rate of change (dT_{atf}/dt or simply dT/dt) of the detected oil temperature (T_{atf}). As can be appreciated from the last stage of Fig. 8, a torque-reduction rate or amount is determined on the basis of both the instantaneous value T_{atf} of the oil temperature and the

differentiated value dT/dt. Fig. 9 shows the relationship among the derivative or the differentiated value (dT/dt), the instantaneous oil temperature value (T_{atf} or simply T), and the torque-reduction rate expressed in a percentage. The pre-programmed information as shown in Fig. 9 is stored in the computer memory (usually RAM). As seen in Fig. 9, the higher the instantaneous oil temperature value T_{atf} and also the greater the time rate (dT/dt) of rise in the oil temperature (that is the steeper the oil-temperature rise), the greater the torque-reduction rate is designed to be set. According to the first modification of the system shown in Figs. 8 and 9, if the system detects a rapid temperature rise in transmission-fluid temperature (T_{atf}) on the basis of the arithmetically-computed time rate-of-change (dT/dt) in the oil temperature under a condition in which the detected oil temperature T_{atf} is within the predetermined permissible temperature range, the system predicts that the detected value of oil temperature will exceed the predetermined permissible temperature value soon. Therefore, the system of the modification shown in Fig. 8 can start the torque-reduction control in order to effectively fall the transmission-fluid temperature before the detected value T_{atf} of oil temperature actually exceeds the permissible temperature value. The previously-discussed predictive torque-reduction control of the first modification prevents the detected oil temperature T_{aft} from exceeding the predetermined permissible temperature value and avoids the detected oil temperature from remarkably overshooting the desired temperature limit (the permissible temperature value). Although the system of the first modification shown in

Fig. 8 utilizes the time rate-of-change (dT/dt) of the detected oil temperature (T_{aft}) for prediction of the oil temperature rise, such prediction of temperature rise in transmission fluid may be derived from an instantaneous quantity-of-heat Q, as shown in Fig. 10. As seen in Fig. 10, first, the instantaneous quantity-of-heat Q generated in the torque converter is arithmetically computed or calculated on the basis of both the engine speed Ne and the engine output torque Te. The engine output torque Te may be replaced by a throttle opening TVO or a quantity of air entering the engine cylinders, since the output torque Te correlates with the throttle opening or with the quantity of air entering the engine cylinders. Thereafter, the instantaneous quantity of heat generated in the torque converter is integrated for a predetermined time duration to obtain the value of the integral $\int Qdt$ of the instantaneous quantity-of-heat Q. The system of the second modification shown in Fig. 10 determines the torque-reduction rate on the basis of both the value of the integral $\int Qdt$ of quantity-of-heat Q and the oil temperature T_{atf} detected or measured by the oil temperature sensor 11. In the event that the value of the integral $\int Qdt$ of quantity-of-heat is a comparatively great value, the system of the second modification determines that a rapid oil temperature rise may occur soon. In such a case (owing to the greater value of the integral $\int Qdt$), the system determines or sets a torque-reduction rate even when the detected oil temperature T_{atf} is a comparatively low temperature value, and then executes a torque-reduction control in accordance with the set torque-reduction rate to reduce torque generated by the engine, before the oil

temperature T_{atf} exceeds the permissible temperature value. The previously-noted instantaneous quantity-of-heat Q can be calculated from the following expression as energy loss in the torque converter:

$$Q = K \cdot Ne \cdot Te \cdot (1 - \eta)$$

where K is a gain (a predetermined constant value), Ne is the engine speed (rpm), Te is the engine output torque, and η is the efficiency of the torque converter.

Assuming that a flow rate of air entering into the engine is denoted by Qa, the engine output torque Te is regarded as the following expression:

$$Te = k \times Qa/Ne$$

where k is a predetermined constant value.
From the previously-noted two expressions, the instantaneous quantity-of-heat Q generated in the torque converter is expressed as follows:

$$\begin{aligned} Q &= K \cdot Ne \cdot (k \times Qa/Ne) \cdot (1 - \eta) \\ &= K \cdot k \cdot Qa \cdot (1 - \eta) \\ &= K' \cdot Qa \cdot (1 - \eta) \end{aligned}$$

Alternatively, predetermined or pre-programmed map data, which is indicative of the relationship among the instantaneous quantity-of-heat Q, the engine speed Ne, and the throttle opening (or the quantity Qa/Ne of air entering the engine cylinders), may be pre-stored in the computer memory included in the system, and the instantaneous quantity-of-heat Q may be retrieved from the map data stored in the memory.

In the previously-described embodiment and modifications, during the torque-reduction control, the quantity of air entering the engine is reduced by decreasing the throttle angle opening of throttle valve 4, thereby reducing the engine output torque. As a method of torque reduction, instead of decreasing the

throttle opening TVO, ignition timing may be retarded or the air/fuel mixture ratio may be changed to leaner. Also, in the previously-discussed embodiment and modifications, the input information signal (T_{atf}) detected by the oil temperature sensor 11 is used as a control parameter necessary for the torque-reduction control (or the transmission-fluid temperature control). A temperature of atmospheric air around the transmission fluid (ATF) or a temperature of the transmission case may be used in place of the transmission-fluid temperature T_{atf}.

Referring now to Figs. 1 and 2, the block diagram of Fig. 1 indicates the fundamental construction of the system related to the embodiment, while the block diagram of Fig. 2 indicates the fundamental construction of the system related to the first and second modifications. As seen in Fig. 1, a temperature detection means detects a temperature of transmission fluid (simply an oil temperature) or a transmission temperature correlating with the transmission-fluid temperature. An engine output torque reduction means operates to continuously reduce the engine power output (the engine output torque) when the transmission temperature detected by the temperature detection means is above a predetermined temperature value. According to the construction shown in Fig. 1, when the transmission temperature (or the transmission-oil temperature) becomes greater than the predetermined temperature value (the permissible temperature value), the quantity of heat generated in the torque converter can be suppressed effectively by reducing the engine output torque (see Fig. 6).

On the other hand, as seen in Fig. 2, the system of the invention may include a temperature rise

prediction means predicts a temperature rise in a transmission-fluid temperature or a transmission temperature correlating with the transmission-fluid temperature which may exceed a predetermined temperature value or more in the near future or soon. An engine output torque reduction means operates to continuously reduce the engine output torque when the temperature rise prediction means determines that a temperature rise predictive of the transmission temperature exceeding the predetermined temperature value takes place. According to the construction of the shown in Fig. 2, when it is predictable that the transmission temperature (or the transmission-oil temperature) will exceed the predetermined temperature value (the permissible temperature value) (see Fig. 6), the system operates to predictively suppress the quantity of heat generated in the torque converter by way of reduction in the engine output torque so that the transmission temperature (the transmission-fluid temperature) never exceeds the predetermined temperature value (the permissible temperature value). For instance, the previously-noted temperature correlating with the transmission-fluid temperature corresponds to a temperature of atmospheric air around the transmission fluid or a temperature of the transmission case. The system shown in Figs. 1 and 2 is applicable to an automatic transmission with a lock-up torque converter in which a control unit for an automatic shift control and a lock-up control is integrally provided in a transmission case. Preferably, the previously-noted engine output torque reduction means is designed to reduce the engine output torque with a greater torque-reduction rate when the transmission temperature (the transmission-fluid temperature) and/or

the time rate of rise in the transmission temperature (the transmission-fluid temperature) is higher. Therefore, as the transmission temperature (the transmission-fluid temperature) becomes higher and/or the temperature rise becomes abrupt, the engine output torque is able to be reduced with a greater torque-reduction rate. Conversely, when the transmission-fluid temperature is low and thus a requirement for torque-reduction is comparatively less, the torque-reduction rate can be suppressed to a smaller value. Thus, the engine output torque reduction means can reasonably reduce the engine output torque during the torque-reduction control, while certainly avoiding excessive temperature rise in the transmission fluid. Furthermore, it is preferable that the system includes a lock-up zone enlargement means for enlarging the lock-up zone of the lock-up clutch employed in the lock-up torque converter, while the engine output torque is continuously reduced by way of the previously-noted engine output torque reduction means. Addition of the lock-up zone enlargement means to the engine output torque reduction means ensures a positive turning-on of the lock up, as well as reduction in the engine output torque, thus enabling the transmission-fluid temperature to be lowered more effectively. Therefore, the system suits to a stronger demand for a great and rapid temperature drop of the transmission fluid. Also, the system may include a highest gear limitation means (or a downshift means) for limiting a shift gear range of the automatic transmission down to a lower speed gear, while the engine output torque is continuously reduced by way of the previously-noted engine output torque reduction means. According to the system having the

highest gear limitation means, in an automatic transmission having a shift gear range of four forward speeds (1st, 2nd, 3rd, 4th gears) and reverse (R) gear positions, when the engine output torque is reduced by the engine output torque reduction means, the shift gear range can be limited to a shift gear range of three forward speeds (1st, 2nd, 3rd gears) and reverse (R) for example. In engine/vehicle conditions in which the highest gear should be shifted to the 4th gear on the basis of the usual shift schedule, the transmission is able to be forcibly positively down-shifted to the 3rd gear. In this case, since a required engine output torque can be lowered owing to the downshifting operation, the engine output torque can be effectively suppressed in addition to torque-reduction caused by the engine output torque reduction means. More preferably, the system may include a warning means (including a warning light, a warning buzzer or the like) for warning the driver that the vehicle is in the torque-reduction control state wherein the engine output torque is continuously reducing by way of the previously-noted engine output torque reduction means. When the warning means is provided, the operative condition state of the engine output torque reduction means, which is provided for forcibly reducing the engine output torque for the purpose of effectively reducing the oil temperature of the transmission fluid or torque converter oil, the warning means (the warning light, the warning buzzer or the like) can certainly signal the driver that the torque-reduction control is now executed by turning on the warning light or by emitting a buzzing sound, for example.

As will be appreciated from the above, in an automatic transmission with a torque converter, a

transmission-fluid temperature control system of the invention can effectively rapidly drop a temperature of transmission fluid by reducing the engine output torque when the temperature of transmission fluid exceeds a predetermined permissible temperature value. This effectively prevents transmission-fluid degradation which may occur when the transmission-fluid temperature remains high. Furthermore, even if the system of the invention may be applied to an automatic transmission in which an automatic transmission control unit is integrally provided in the transmission case, the system can control or regulate the transmission-fluid temperature to a lower temperature value in such a manner as to protect computer components of the automatic transmission control unit from heat damage. Moreover, in the case that the transmission-fluid temperature control system of the invention has the previously-noted temperature rise prediction means, the system can predictively prevent the transmission-fluid temperature from exceeding the predetermined permissible temperature value, thus preventing degradation of the transmission fluid from occurring owing to a transmission-fluid temperature above the permissible temperature value.

While the foregoing is a description of the preferred embodiments of the invention, it will be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the invention as defined by the following claims.

CLAIMS.

1. A control system for regulating temperature of transmission fluid in an automatic power transmission with a torque converter in an automatic vehicle with an electronic engine control system, said system comprising:

temperature detection means for detecting a transmission temperature correlating with a temperature of transmission fluid; and

engine output torque reduction means for continuously reducing engine output torque, when the transmission temperature detected by said temperature detection means is above a predetermined temperature value.

2. The control system for regulating temperature of transmission fluid, as set forth in claim 1, which further comprises temperature rise prediction means for predicting a rise in the transmission temperature above a predetermined temperature value, said engine output torque reduction means reducing the engine output torque when said temperature rise prediction means determines that a temperature rise predictive of the transmission temperature above the predetermined temperature value occurs.

3. The control system for regulating temperature of transmission fluid, as set forth in claim 1, wherein said transmission temperature correlating with a temperature of transmission fluid is a transmission-fluid temperature.

4. The control system for regulating temperature of transmission fluid, as set forth in claim 1, wherein said transmission temperature correlating with a temperature of transmission fluid is a temperature of atmospheric air around the transmission fluid.

5. The control system for regulating temperature of transmission fluid, as set forth in claim 1, wherein said transmission temperature correlating with a temperature of transmission fluid is a temperature of a transmission case.

6. The control system for regulating temperature of transmission fluid, as set forth in claim 1, wherein said engine output torque reduction means reduces the engine output torque down to a lower output torque as the transmission temperature becomes higher.

7. The control system for regulating temperature of transmission fluid, as set forth in claim 1, wherein said engine output torque reduction means reduces the engine output torque down to a lower output torque as the rate of rise in the transmission temperature becomes higher.

8. The control system for regulating temperature of transmission fluid, as set forth in claim 1, which further comprises lock-up zone enlargement means for enlarging a lock-up zone of a lock-up clutch in an automatic transmission with a lock-up torque converter, while said engine output torque reduction means continuously reduces the engine output torque.

9. The control system for regulating temperature of transmission fluid, as set forth in claim 1, which further comprises highest gear limitation means for limiting a shift gear range of the automatic transmission down to a lower speed gear, while the engine output torque is continuously reduced by said engine output torque reduction means.

10. The control system for regulating temperature of transmission fluid, as set forth in claim 1, which further comprises warning means for signalling for a particular state in which the engine output torque is continuously reduced by said engine output torque reduction means.

11. A control system for regulating transmission fluid temperature in an automatic power transmission with a torque converter in an automatic vehicle with an electronic engine control system, the system comprising:

temperature detection means for detecting a transmission temperature correlating with a temperature of transmission fluid;

temperature rise prediction means for predicting a rise in the transmission temperature above a predetermined temperature value; and

engine output torque reduction means for continuously reducing engine output torque, when the temperature rise prediction means determines that a temperature rise predictive of a transmission temperature above the predetermined temperature value occurs.

12. A transmission fluid temperature control system substantially as described with reference to Figure 1, Figure 2, Figure 3, Figure 8, or Figure 10 of the accompanying drawings.

The Patent Office

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Claims searched: 1-12

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G3N (NGA4, NGCA, NGCA4, NGCA5, NGE1, NGE1A, NGE1B); G3R (RBQ47)

Int Cl (Ed.6): F02D 29/00, 29/02; B60K 41/04, 41/06, 41/08, 41/10

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 4815340 (TOYOTA) see column 6 lines 22-63	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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